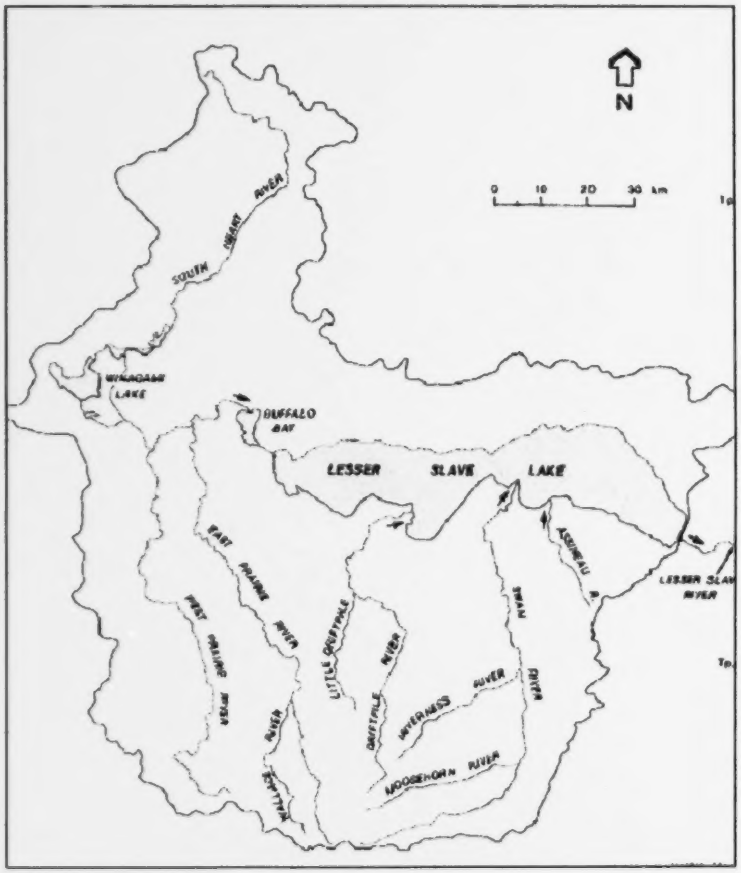
Lesser Slave Lake
Results of Water Quality Survey
Conducted by Alberta Environment
In 2000-2002



Alberta
Environment

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EXECUTIVE SUMMARY

Lesser Slave Lake is the third largest lake in Alberta and supports major sport, commercial and domestic fisheries. It is a popular tourist destination and a recognized biologically significant area for bird life. The lake is a source of water for agriculture, forestry and domestic and municipal uses.

Residents in the Lesser Slave Lake watershed have expressed concerns about the health of their lake and the quality of life it provides. In response to these concerns, AENV conducted comprehensive water quality and limnological investigations in1990-92, which were repeated in 2000-02. This report summarizes the results of the limnological investigations conducted between 2000 and 2002.

Lesser Slave Lake has two main basins (west and east) separated by a constriction about 5 km wide formed by the Swan River delta. Both of the main basins and the lake outfall were sampled for detail chemical analyses. Limnological assessments were done on samples collected from central areas of the lake.

Results of the limnological investigations obtained in 2000-02 were similar to the 1990-92 study results. The investigations showed that the lake is well mixed due to wind action and thermal stratification is week and transitory. Mixing allows good oxygen distribution throughout the water column. Levels of dissolved and suspended solids are low in the central areas of the lake and turbidity is mainly due to high algae levels.

Concentrations of nutrients (nitrogen and phosphorus) are moderately high. The west basin has had consistently higher concentrations of nutrients compared to the east basin. Concentrations of chlorophyll-*a*, the main measure of algal density, have been high for the amount of phosphorus present. In terms of chlorophyll-*a* levels, the west and east basins rank very high on the productivity scale for Alberta lakes and can be categorized as hypereutrophic (super productive).

Most water quality variables, including metals, trace elements and pesticides, complied with Alberta Surface Water Quality Guidelines for the protection of aquatic life. Occasionally, total nitrogen and total phosphorus levels exceeded the guidelines reflecting the very productive nature of the lake.

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1.0 INTRODUCTION

1.1 Report Objectives

The objectives of this report are:

- To summarize results of limnological and water quality investigations conducted by Alberta Environment (AENV) on the Lesser Slave Lake in 2000 and 2001 and on the lake outfall between 2000 and 2002.
- To provide a comparison between results from this and an earlier limnological study carried out by AENV between 1991-1993.

1.2 Background

Lesser Slave Lake (LSL) is the third largest lake in the province, a popular tourist destination and a recognized biologically significant area for bird life. The lake is a source of water for agriculture, forestry, and recreation/tourisms, domestic and municipal uses. It supports major sport, commercial and domestic fisheries.

There are several beaches, campsites, recreation areas, cottages and two large provincial parks around the lake. Communities located on the shores of the lake include the Town of Slave Lake, the village of Kinuso, the hamlets of Grouard, Joussard, Faust and Canyon Creek and the First Nation communities of Kapawe'no, Sucker Creek, Driftpile, Swan River, and Sawridge.

Residents in the LSL watershed have been concerned with the health of their lake, and the quality of life that it provides. Concerns have perhaps been greatest for high densities of algae and undesirable algal blooms. The lake is a source of drinking water for the Town of Slave Lake and First Nation communities located around the lake therefore water quality is very important to those communities.

In response to various water management concerns AENV conducted a comprehensive water quality and limnological investigations between 1991-1993. The two main basins of the lake, five tributaries and the lake's outflow were sampled monthly during the ice-free season. Results of these investigations are presented in Noton (1998).

The subsequent water quality investigations of the lake and its outfall were conducted by AENV between July 2000 and January 2002. This report presents the results of these field surveys.

1.3 Lake and Drainage Basin Characteristics

The details on lake and drainage basin characteristics can be found in Mitchell and Prepas (1990) and Noton (1998). The basic physical features of the lake are presented in Table 1.

Table 1 Physical characteristics of Lesser Slave Lake (Noton 1998)

Area (incl. Buffalo Bay)	1,160 km^2
Volume	13,200 x 10^6 m^3
Maximum depth	20.5 m (east) 15. 5 m (west)
Mean depth	11.4 m
Shoreline length	241 km
Mean annual surface inflow	1,550 x 10^6 m^3
Mean water residence time	9.5 yr
Drainage basin area (excl. lake)	12,400 km^2

The drainage basin of LSL is large and covers an area about 11 times greater than the lake. Much of the inflow water enters the western end of the lake at Buffalo Bay via the South Heart River and the East Prairie River. On the southern shore of LSL, the three largest tributaries are the Driftpile, Swan and Assineau rivers, which drain the southern part of the watershed. Many small creeks and intermittent streams also flow into the lake. The outflow to the Lesser Slave River is located at the lake's east end. The Lesser Slave River joins the Athabasca River about 75 km downstream of the outlet.

1.4 Past Water Quality Investigations

Detailed information on water quality in LSL was not available prior to 1991. The Provincial Department of Health collected three samples in August and September of 1970 and Fish and Wildlife Division gathered some limnological data prior to 1974 and summer of 1975. In February 1989, AENV collected a single series of samples from four depths in the east basin. Results of these investigations are presented in Mitchell and Prepas (1990).

The first comprehensive water quality investigation was conducted by AENV between 1991-1993. These investigations showed the lake was well mixed by wind action and thermal stratification was weak and transitory. It was well oxygenated even in winter and much of the water column contained more than 5 mg/L of dissolved oxygen year round. Turbidity in the central areas of the lake was mainly due to algal blooms. Concentrations of main nutrients (nitrogen and phosphorus) were moderately high. Concentrations of chlorophyll-*a*, the main measure of algal density, were very high for the amount of phosphorus present (Noton 1998). Moderate blooms of blue-green algae turned the lake water green during late summer. The extent of aquatic vegetation is limited by heavy wave action, except in Buffalo Bay, where there are extensive weed beds.

A nutrient budget prepared to evaluate lake's internal and external phosphorus sources showed that the net internal release of total phosphorus from lake bottom sediments nearly double the external supply (Noton 1998). No obvious opportunities for significantly reducing the

phosphorus supply to LSL were apparent. Noton (1998) concluded that to avoid exacerbating nutrient and algal conditions, phosphorus input should not be allowed to increase.

Most water quality variables complied with the provincial and federal water quality guidelines for the protection of aquatic life. The study allowed the conclusion that LSL is a biologically productive, freshwater lake. The main concern with respect to water quality is the high nutrient and algal content, particularly in the West Basin.

2.0 METHODOLOGY

The LSL limnological surveys were carried out on:

- July 28, 2000
- August 30, 2000
- October 5, 2000 and
- February 21, 2001.

To represent overall water quality in each of the two main basins of the lake (West Basin and East Basin), 10-point composite samples were collected from the euphotic zone[1] in the areas indicated on Figure 1. Depth profiles of temperature, oxygen, light penetration, conductivity and grab samples of other variables were taken at the profile sites in the two basins. Grab samples representing lake outfall water for detail chemical analyses along with *in situ* measurements were collected periodically between March 2000 and January 2002. Sampling sites are shown on Figure 1 and are listed in Table 2.

All field methods followed the standard procedure of AENV (AEP 1993, AENV 2002). Replicate and field blank samples were collected for quality assurance. After rigorous data validation, the survey data were input to the AENV surface water quality database and are available to the public (swq.requests@gov.ab.ca).

Table 2 Sampling sites

Station Number	Station Description	Latitude	Longitude
AB07BG0030	LSL West Basin Euphotic Composite	55°31'57"	115°53'25"
AB07BG0040	LSL West Basin Profile	55°31'57"	115°53'25"
AB07BJ0040	LSL East Basin Euphotic Composite	55°26'40"	115°01'11"
AB07BJ0050	LSL East Basin Profile	55°26'40"	115°01'11"
AB07BK0010	LSR at Bridge Near Outfall from LSL	55°18'22"	114°45'35"

[1] Euphotic Zone - the water stratum from the surface to the depth of 1% light penetration. The zone of effective photosynthesis.

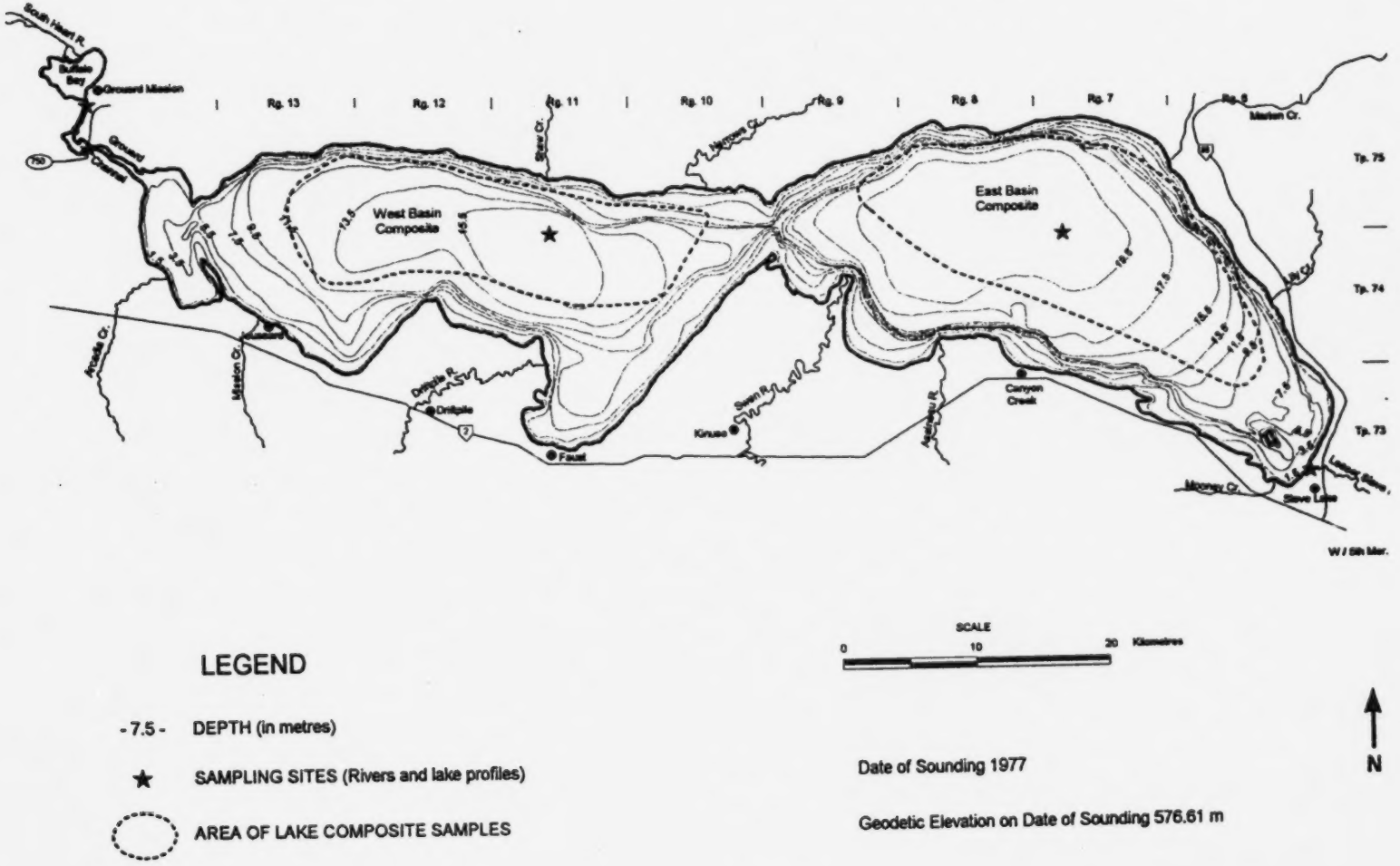


Figure 1 Sampling site locations and areas

3.0 RESULTS

3.1 Temperature, Oxygen and pH Profiles

Temperature, oxygen and pH profiles are depicted on Figures 2-3. Both basins show no distinctive thermal stratification in the summer with the exception of the East Basin where the temperature gradient of less than 5°C was measured on July 28th at the depth of about 12 meters. In February, the temperature gradient between the surface and the bottom water temperature was about 3.5°C for the West Basin and about 2.5°C for the East Basin. The upper portion of the West Basin was warmer by about 2°C in July, otherwise the East Basin showed generally slightly higher temperatures. The 1991-93 data also show the lake was well mixed and thermal stratification was weak and transitory.

The East Basin was well oxygenated with no significant drop in oxygen levels throughout the upper water column with the oxycline[2] at about 12 meters in July and about 14 meters in February. The upper West Basin is also well oxygenated but the oxygen levels dropped at the depth of about 10 meters to a level below 5 mg/L in July. In February, the oxycline was observed at the depth of about 8 meters with the gradual decline in the oxygen level to less than 5 mg/L at about 10 meters. Similarly, during the 1991-93 study period, no oxygen deficiency was recorded in the main body of the lake and oxygen levels remained within the Alberta Surface Water Quality Guidelines (ASWQG) for the protection of aquatic life (Noton 1998).

Surface pH varied between 7.76 and 8.99 in the East Basin and between 7.96 and 8.49 in the West Basin. No significant variations in the pH levels were measured in the water column of either East or West basins and pH levels remained within the ASWQG.

3.2 Ions and General Water Chemistry

Analytical results of composite samples from the West and East basins are summarized in Table 3. These results indicate that the water is of calcium bicarbonate type and moderately alkaline (89 – 98 mg/L $CaCO_3$). Levels of Total Dissolved Solids were relatively low for the central Alberta lakes and ranged between 105 and 118 mg/L. Slightly (generally less than 10%) higher levels of dissolved solids were measured in the West Basin than in the East Basin. Conductivity profiles (Figure 4) show little vertical variations with the exception of February when the higher than average levels (above 200 µS/cm) were measured in the upper 2-4 meters. All these values fall within the range measured in the past.

Total Suspended Solids were low and ranged between 2 and 6 mg/L. Color varied between 6 and 22 RCU (Relative Color Units) and its levels were very similar in both basins. In the past generally the West Basin has had somewhat higher color levels than the East Basin.

[2] Oxycline - A horizontal boundary layer in the water column, at which dissolved oxygen content changes sharply with depth.

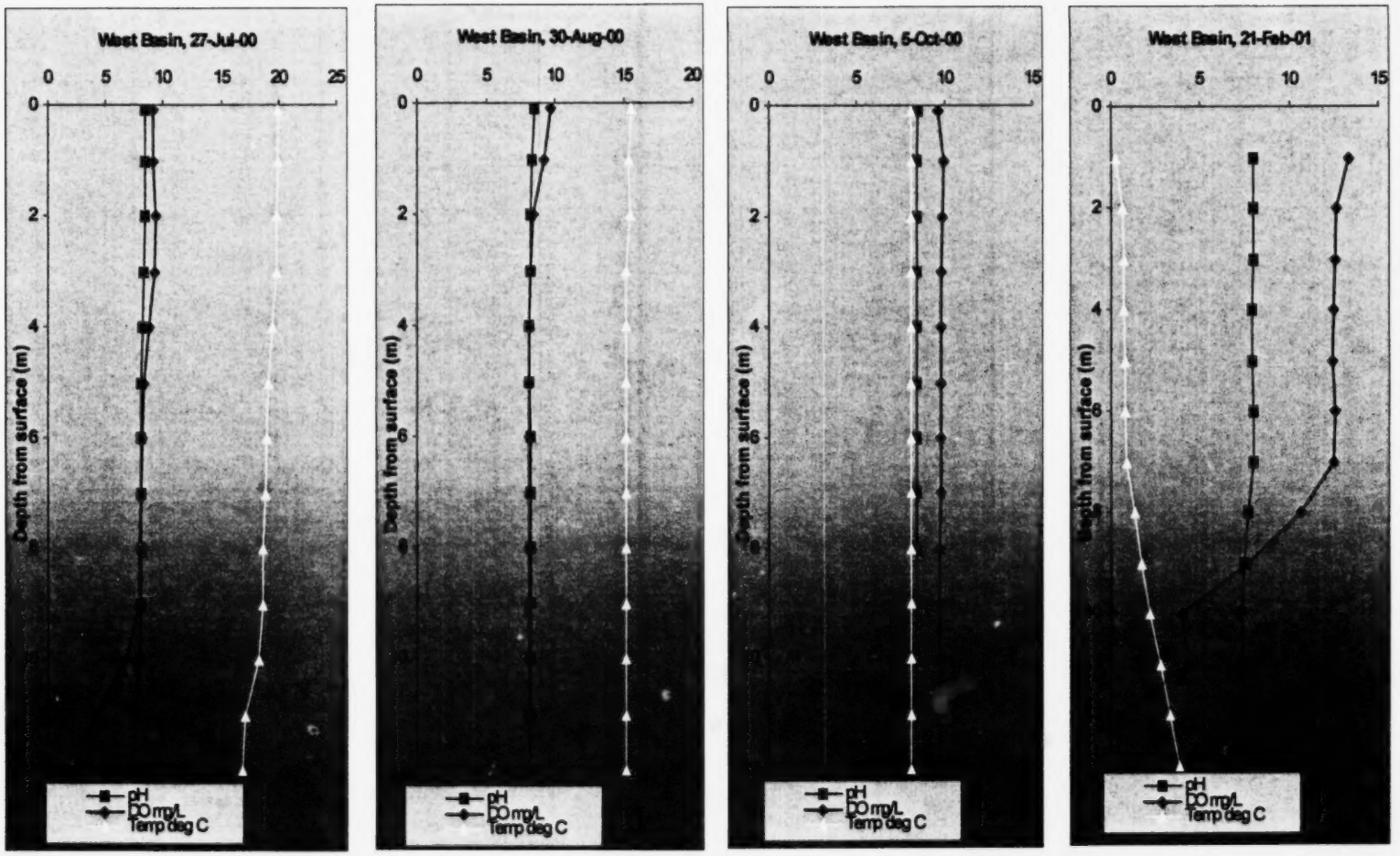


Figure 2 Temperature, dissolved oxygen and pH profiles in West Basin

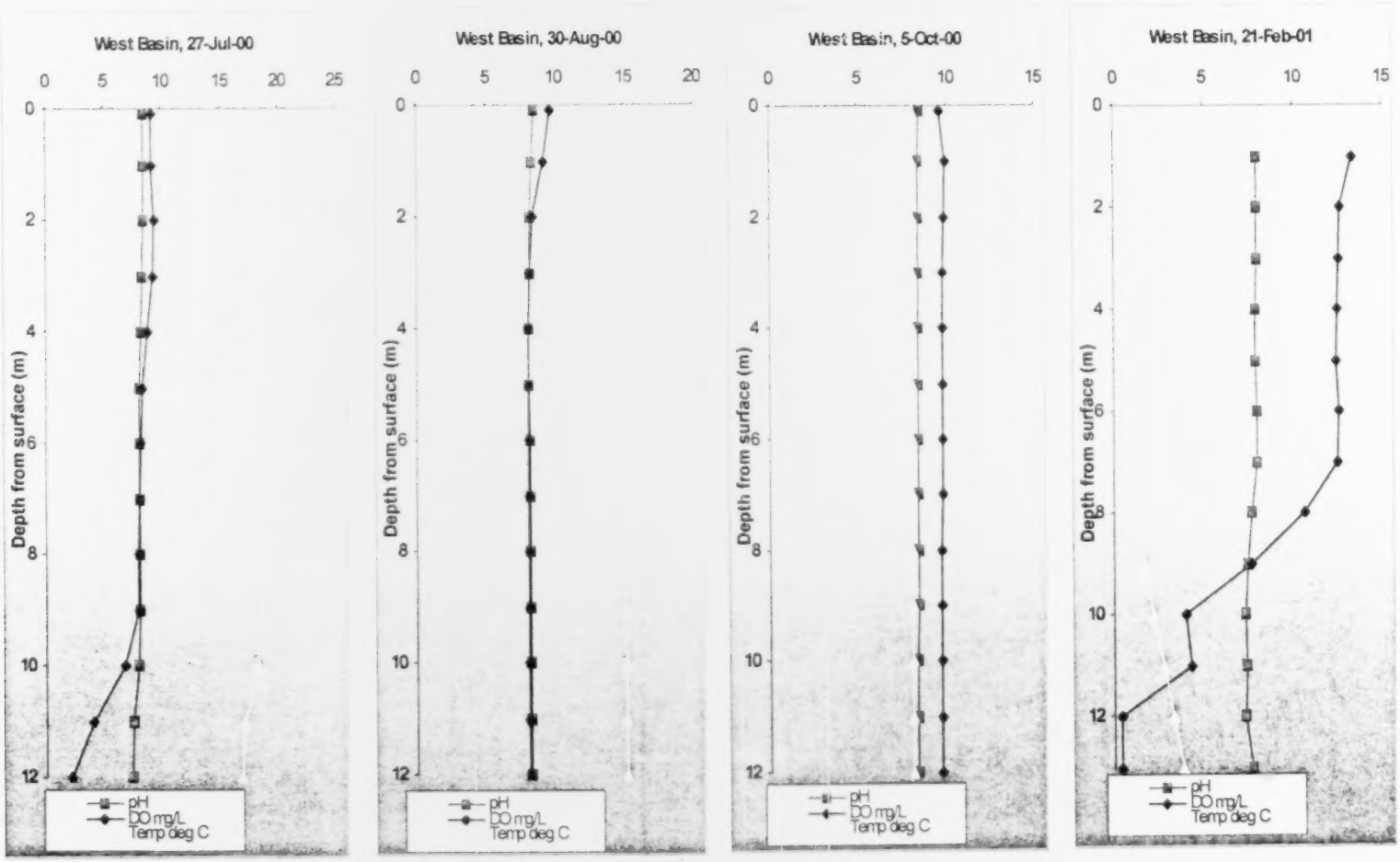


Figure 2 Temperature, dissolved oxygen and pH profiles in West Basin

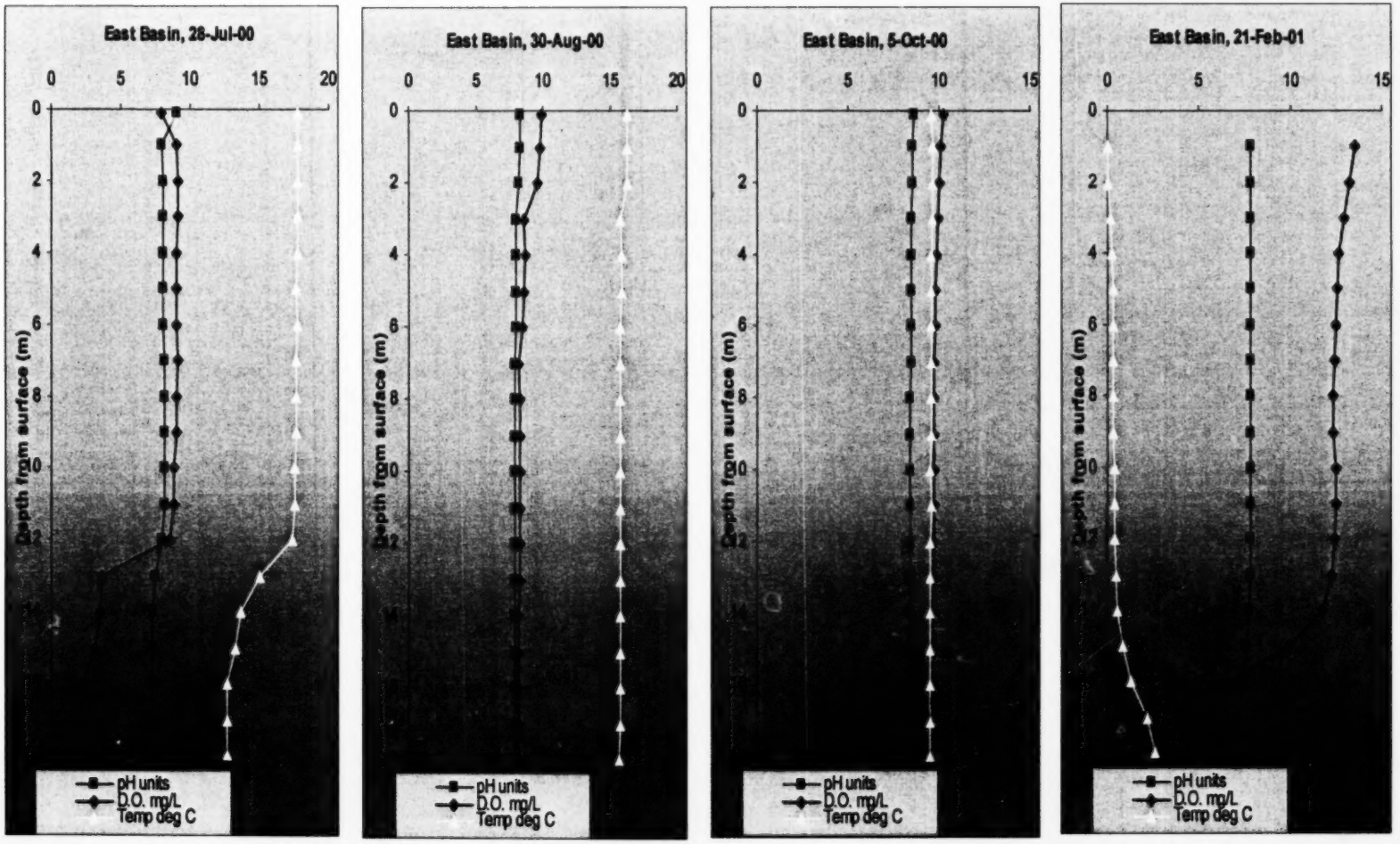


Figure 3 Temperature, dissolved oxygen and pH profiles in East Basin

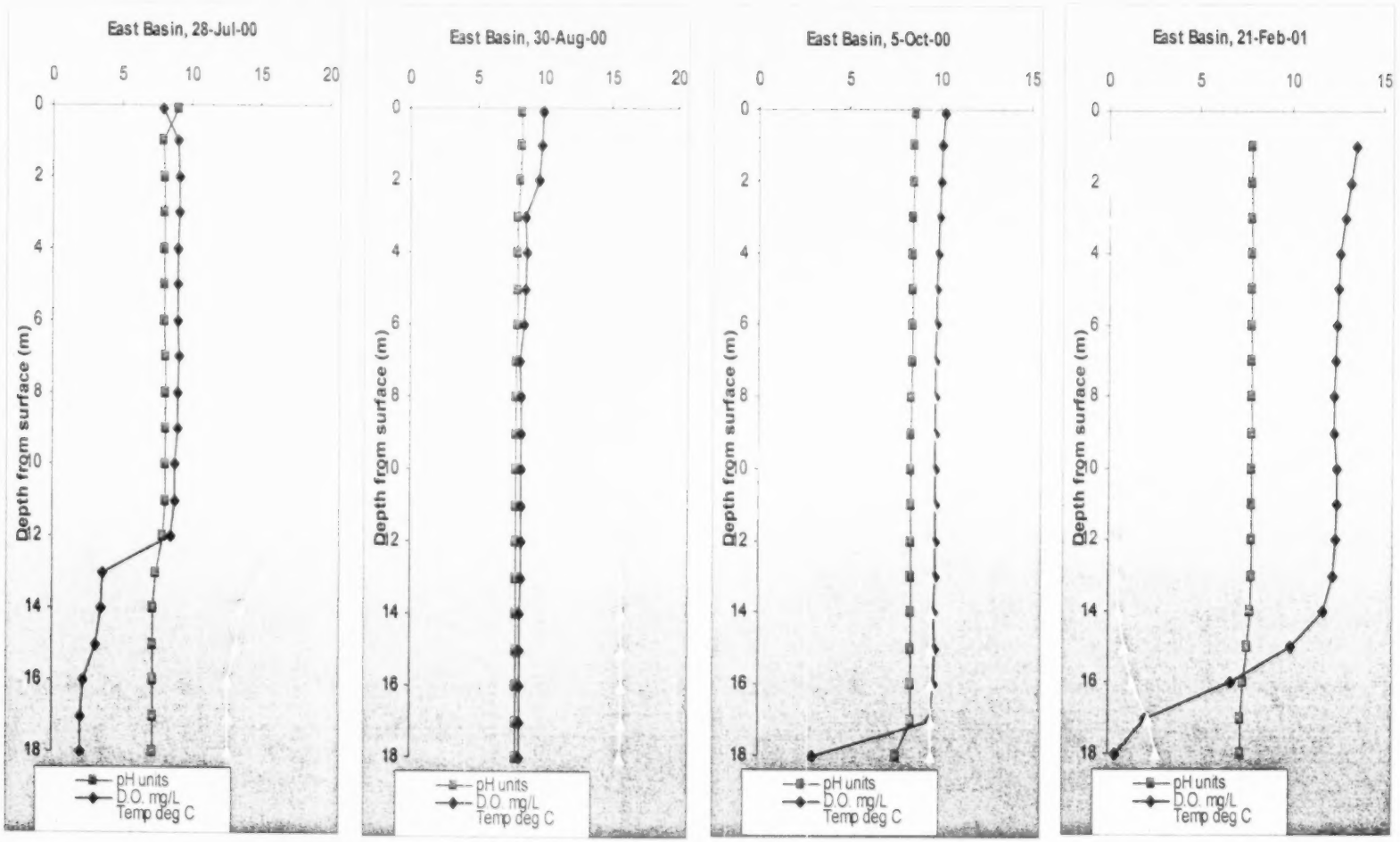


Figure 3 Temperature, dissolved oxygen and pH profiles in East Basin

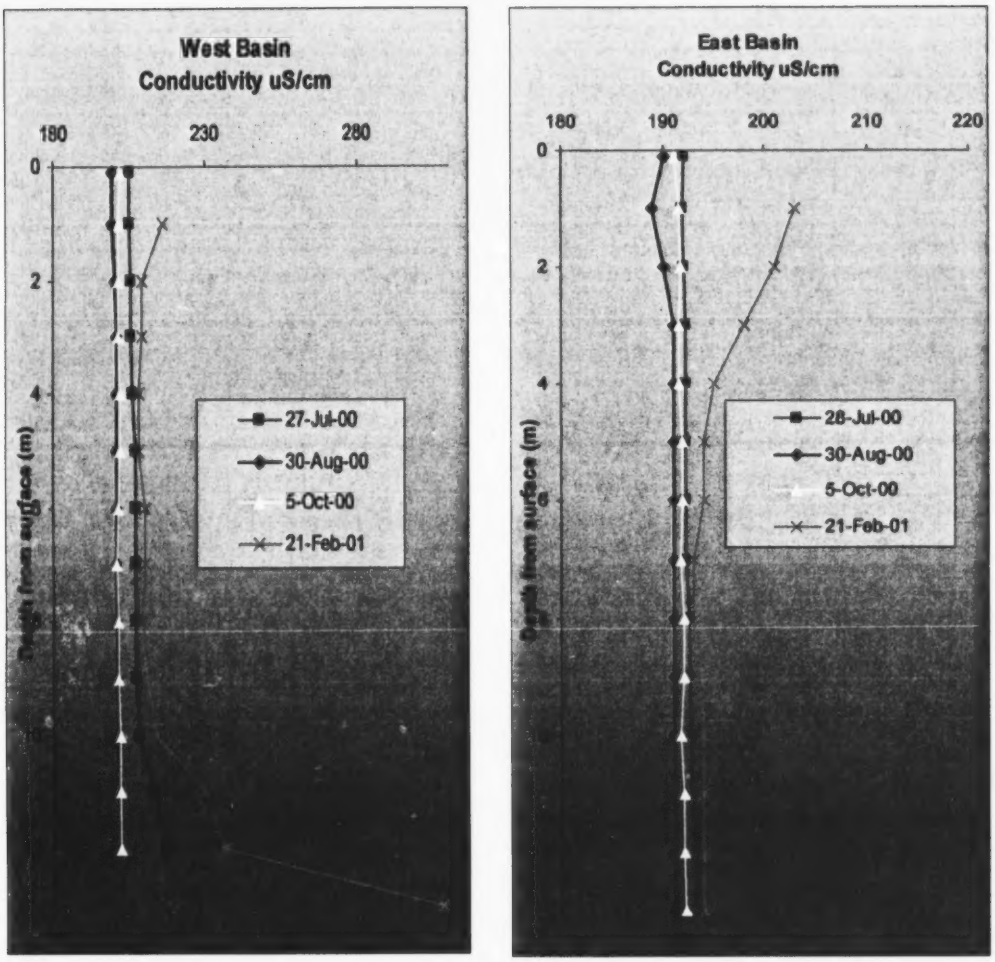


Figure 4 Conductivity profiles for East and West Basins

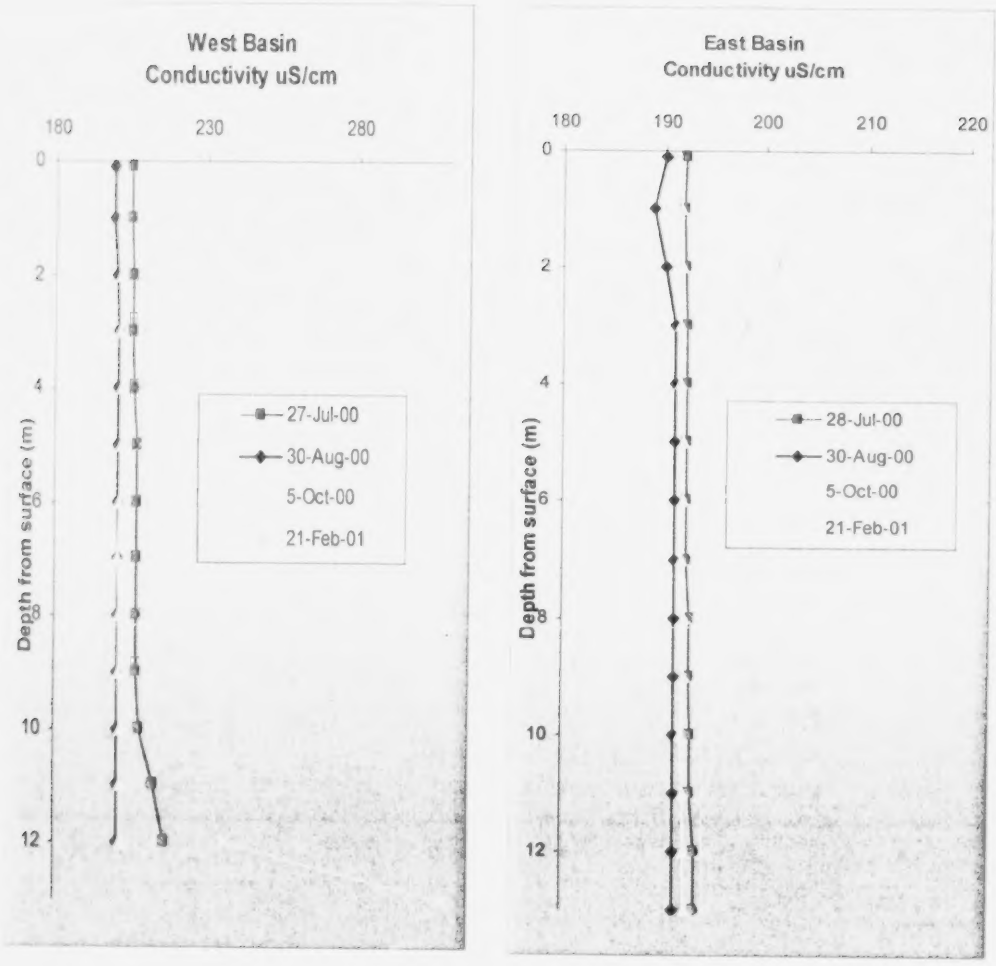


Figure 4 Conductivity profiles for East and West Basins

Table 3 Results of Analyses of Composite Samples Collected in 2000 and Historic Averages

Station:	West Basin Euphotic Composite				East Basin Euphotic Composite			
Sample Date:	27-Jul	30-Aug	5-Oct	Historic Average	28-Jul	30-Aug	5-Oct	Historic Average
Alkalinity Phenolphthalein $CaCO_3$ mg/L	<1	<1	<1	*	<1	<1	<1	*
Alkalinity Total $CaCO_3$ mg/L	95	98	96	93	89	92	93	88
Ammonia Dissolved mg/L	0.032	0.012	0.029	0.025	0.009	0.008	0.018	0.013
Bicarbonate mg/L	116	119	117	113	109	112	113	107
Carbon Dissolved Organic mg/L	10.4	10.5	10.5	11.4	9.4	9.3	10.8	9.6
Chloride Dissolved mg/L	2.9	1.3	2.1	*	1	1.8	1.8	*
Chlorophyll-*a* mg/m^3	11.1	107.2	39.1	54.3	6.3	53.4	90.9	27
Colour True TCU	6	19	22	16	7	19	22	13
Fluoride Dissolved mg/L	0.09	0.09	0.1	*	0.09	0.09	0.1	*
Hardness Total (Calcd_) $CaCO_3$ mg/L	90	95	83	85	83	86	80	81
Nitrogen Dissolved Nitrite mg/L	<0.001	0.001	0.004	*	<0.001	<0.001	0.002	*
Nitrogen Dissolved NO_3 & NO_2 mg/L	0.007	<0.005	0.015	0.007	0.005	<0.005	<0.005	0.008
Nitrogen Total Kjeldahl (TKN) mg/L	0.63	1.37	1.05	1.06	0.5	1.09	1.26	0.63
PH (Lab) pH units	8.07	8.08	7.88	7.6-8.5	8.18	8.24	7.85	7.7-8.4
Phosphorus Total (P) mg/L	0.0317	0.0868	0.0662	0.0485	0.0186	0.0698	0.048	0.0282
Phosphorus Total Dissolved mg/L	0.0087	0.0128	0.0124	0.0122	0.0062	0.0076	0.0077	0.008
Potassium Dissolved/Filtered mg/L	2.6	2.6	2.7	2.6	2.5	2.4	2.6	2.4
Residue Nonfiltrable mg/L	2	6	6	3.3	2	5	4	3.1
Residue Total mg/L	146	158	188	*	136	148	138	*
Secchi Disk Transparency m	3.1	0.7	2	2	3.8	1.7	1.75	2.6
Silica Reactive mg/L	1.6	3.6	3.4	3.8	0.8	1.8	0.4	1.6
Sodium Dissolved/Filtered mg/L	9.1	8.5	9	7.7	8	8.4	8.4	7.4
Sulphate Dissolved mg/L	15	11	7	*	11	11	9	*
Sum of Anions meq/L	2.29	2.23	2.12	*	2.04	2.11	2.11	*
Sum of Cations meq/L	2.27	2.33	2.12	*	2.07	2.15	2.02	*
Total Dissolved Solids mg/L	118	116	108	*	105	109	107	*
Total Dissolved Solids mg/L	144	152	183	*	134	143	134	*

* Historic (1991-1993) averages were not calculated if the dataset contained values "less than" or below detection limits

3.3 Nutrients and Trophic State

Nutrient and chlorophyll-*a*[3] levels measured during the 2000-2001 surveys along with the average nutrient levels from the 1991-1993 studies are given in Table 3. The West Basin has had continuously higher concentrations of nutrients and chlorophyll-*a* than the East Basin (Figures 5 and 6). Total Phosphorus levels varied between 0.0317 and 0.0868 mg/L in the West Basin and between 0.0186 and 0.0698 mg/L in East Basin. Chlorophyll-*a* levels ranged from 11 to 107 mg/m^3 in West Basin and from 6.3 to 90.9 mg/m^3 in the East Basin. Levels of Total Phosphorus and Total Nitrogen exceed the Alberta Surface Water Quality Guidelines (ASWQG, AEP 1999) especially during late summer. It is likely that higher water temperatures and higher loadings of nutrients and organic carbon contribute to higher productivity of the West Basin compared to the East Basin. Nutrient and chlorophyll-*a* levels are within the range measured in the past.

The previous study (Noton 1998) showed that phosphorus was being released from bottom sediments in spring and summer contributing to peak phosphorus levels in late summer. For the recent study, the depth profile data were taken only in February 2001, which does not provide sufficient information to comment on nutrient recycling in the lake. However, as was observed in the 1991-1993 studies, the highest phosphorus concentrations occurred in late summer (Figure 5).

Figure 7 presents levels of photosynthetically active radiation (PAR) representing light (400-700nm) that can be photosynthesized by plants. PAR measurements indicate that the euphotic zone is less than 2 m below the lake surface.

Average summer chlorophyll-*a* and phosphorus concentrations are ranked with that of other Alberta lakes in Figure 8. In terms of chlorophyll-*a* levels, both basins rank very high on the productivity scale being hypereutrophic (super productive). Based on the total phosphorus concentrations, the East Basin and West Basin fall within mesotrophic (medium productive) and eutrophic (very productive) categories respectively.

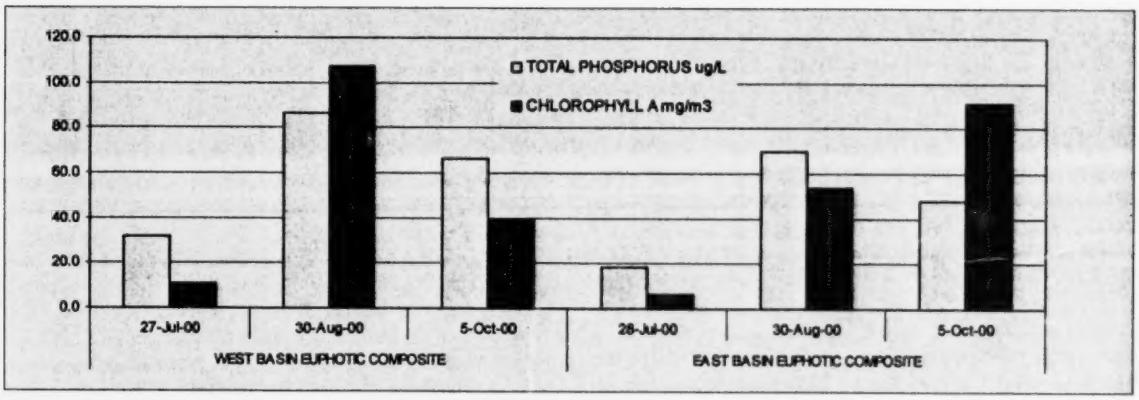


Figure 5 Total phosphorus and chlorophyll-*a* concentrations

[3] Chlorophyll-*a* is a variable used to measure the amount of algae suspended in the water (the phytoplankton).

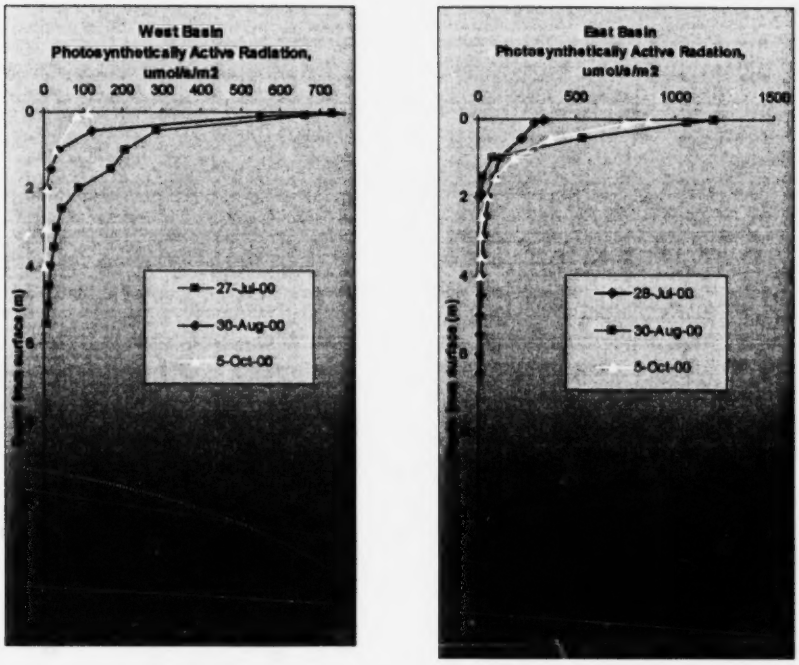


Figure 6 PAR results for West and East Basins

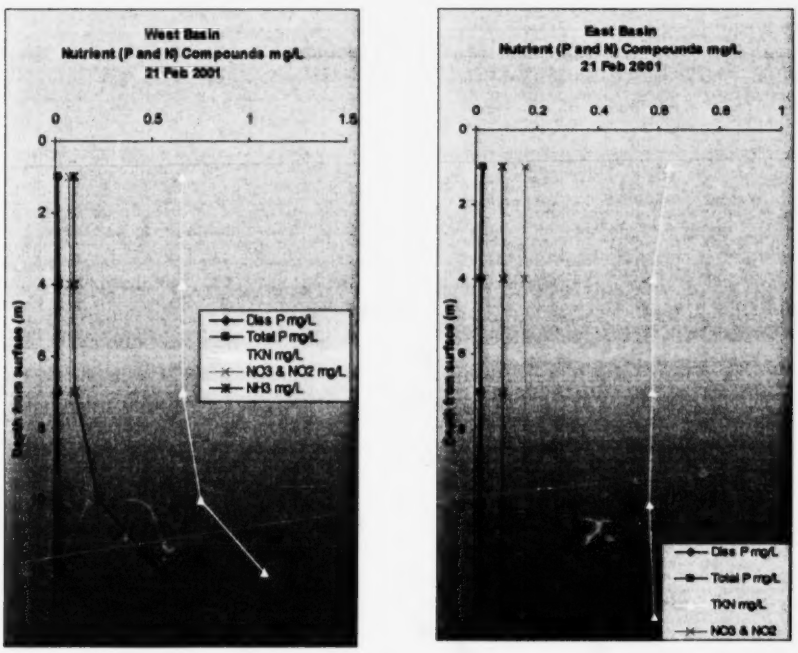
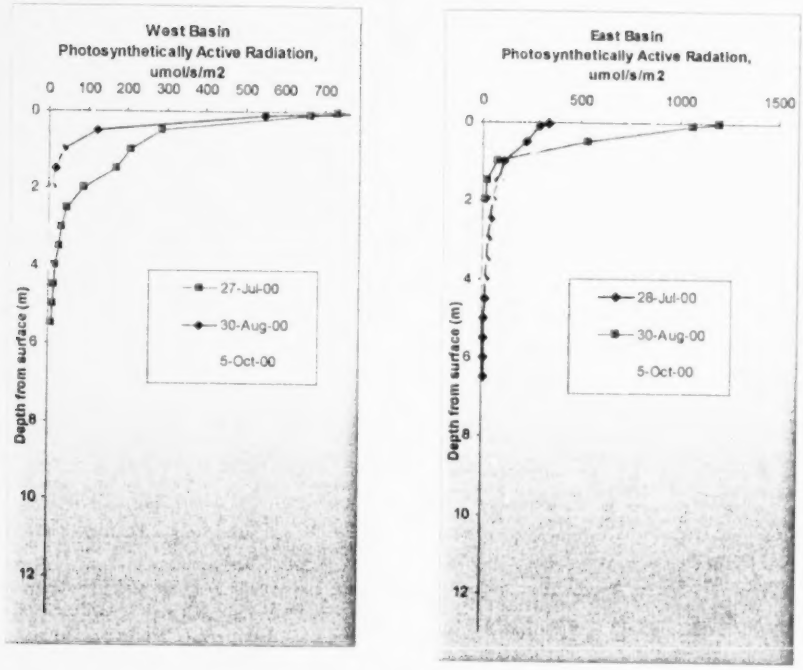


Figure 7 Nutrient profiles for West and East Basins



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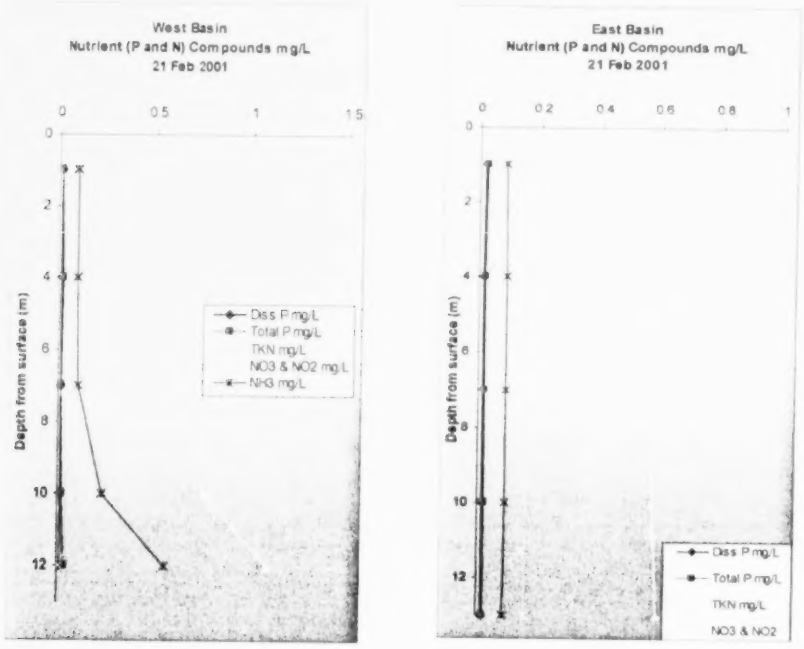

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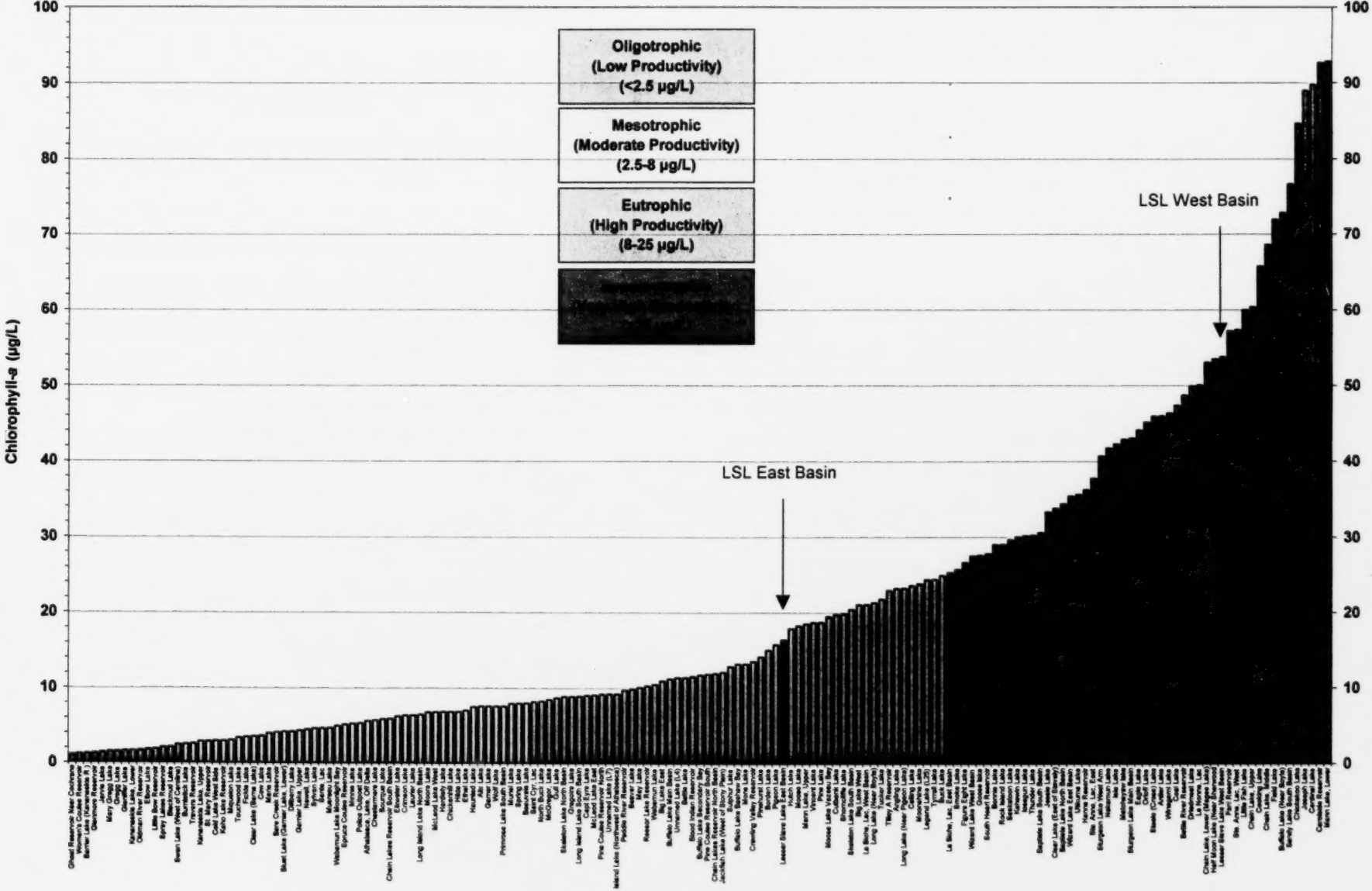
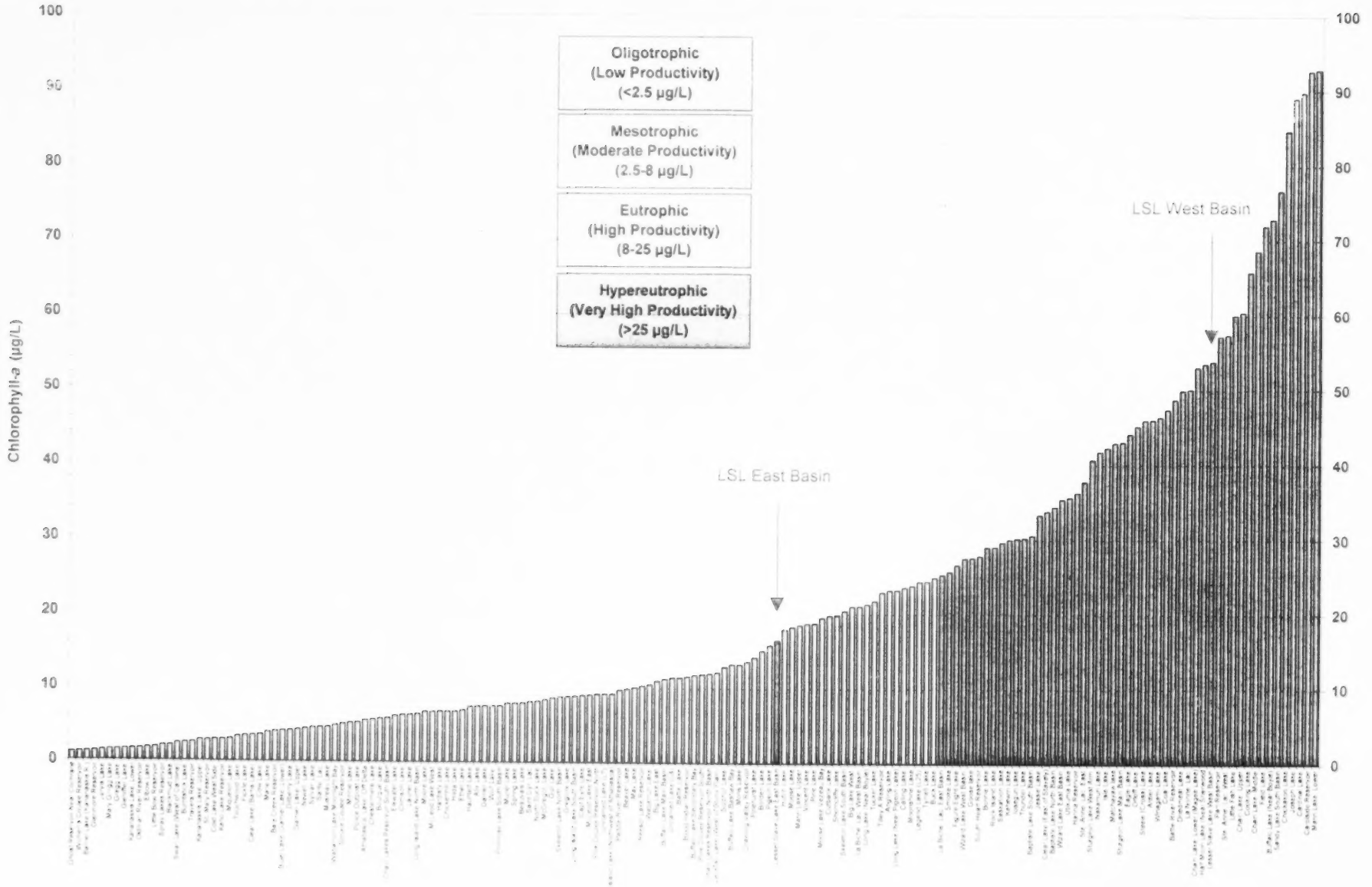


Figure 8a Comparison of trophic status based on average summer chlorophyll-*a* concentrations of Lesser Slave Lake to other Alberta lakes



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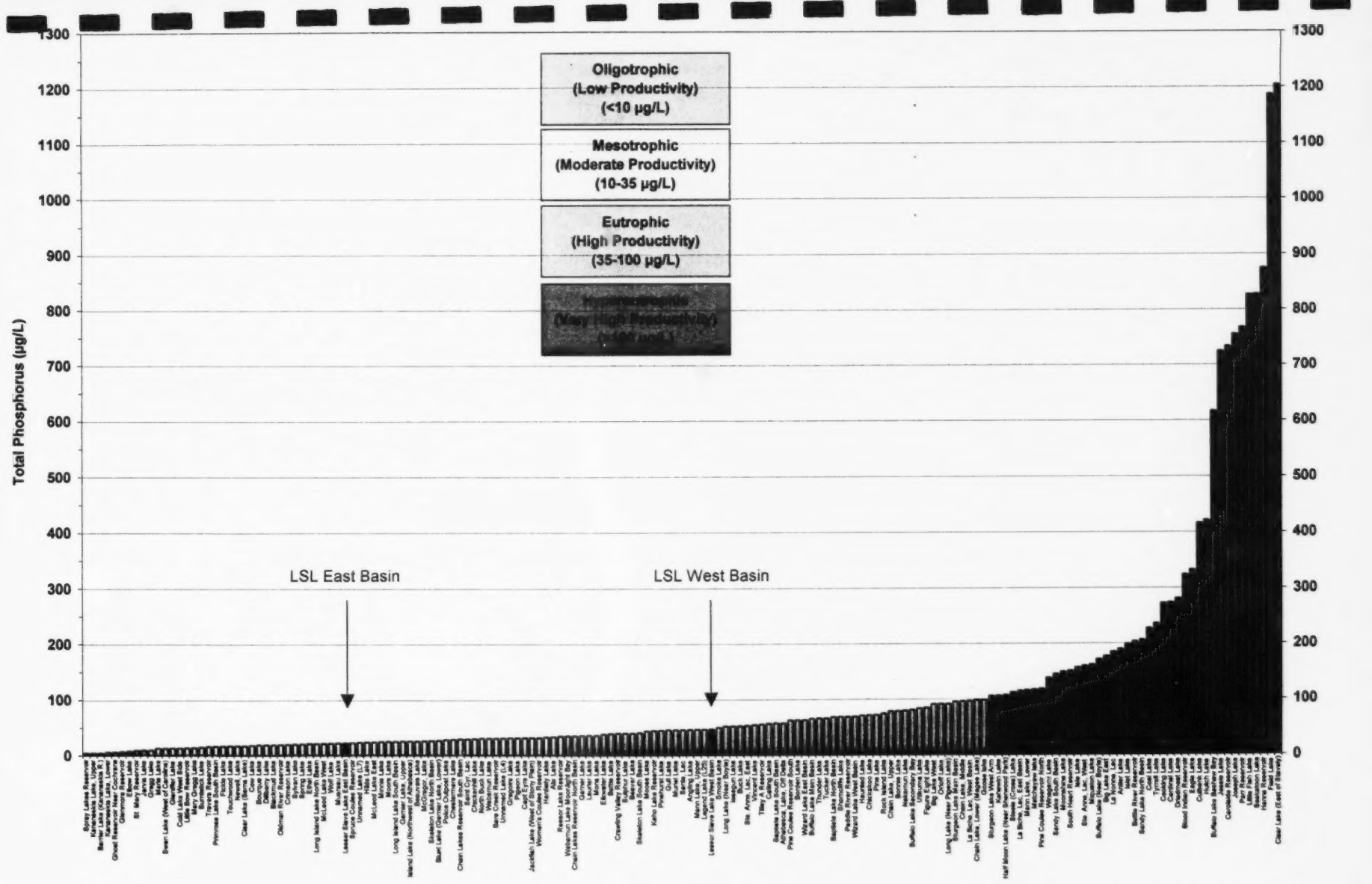

Figure 8b Comparison of trophic status based on average summer total phosphorus concentrations of Lesser Slave Lake to other Alberta lakes

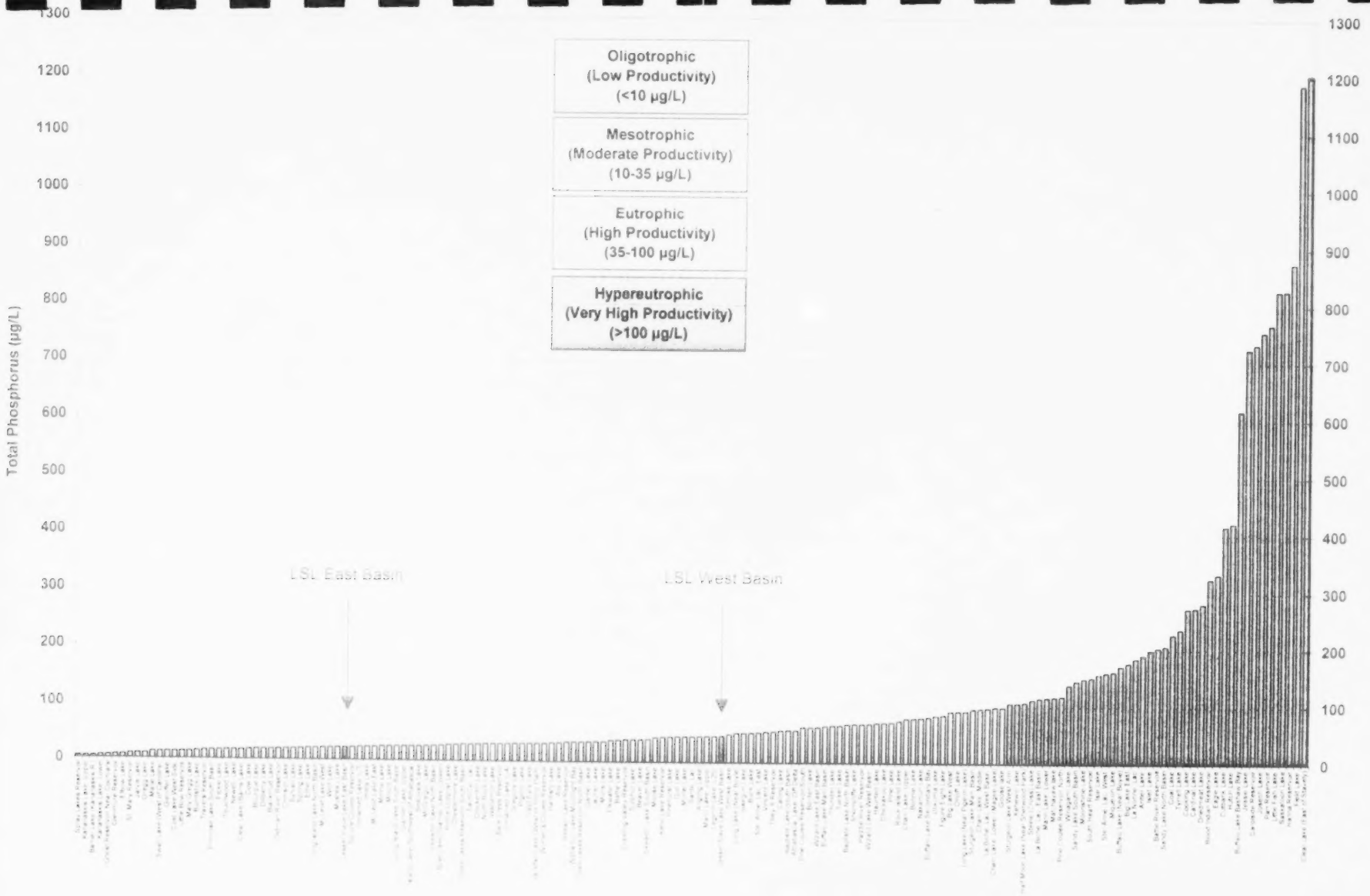

Figure 8b Comparison of trophic status based on average summer total phosphorus concentrations of Lesser Slave Lake to other Alberta lakes

3.4 Metals and Trace Elements

Levels of metals and trace elements measured in composite samples collected from euphotic zones of the lake (Table 4) comply with the ASWQG for the protection of freshwater aquatic life (AEP 1999).

Table 4 Metal and trace element concentrations in composite samples from euphotic zone

Total Elements	Units	West Basin Euphotic Composite			East Basin Euphotic Composite		
		27-Jul-00	30-Aug-00	5-Oct-00	28-Jul-00	30-Aug-00	5-Oct-00
Ag	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Al	µg/L	3.9	17.9	76	15.1	7.4	46.5
As	µg/L	1.67	2.42	2	0.95	1.35	1.3
B	µg/L	18.5	19.7	21	17.2	20.2	20.1
Ba	µg/L	53.2	46.9	51.2	52.1	50.6	51.9
Be	µg/L	0.042	<0.04	<0.04	<0.04	<0.04	0.047
Bi	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ca	mg/L	27.8	27.3	26.2	25.3	25.3	25.2
Cd	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	µg/L	0.03	0.05	0.1	L0.02	0.02	0.06
Cr	µg/L	0.2	<0.1	0.24	<0.08	0.1	0.17
Cu	µg/L	0.48	0.52	1	0.79	0.52	0.81
Fe	µg/L	31	59	97	23.4	18	34
Li	µg/L	8.8	12.1	12.3	16.4	11.9	11.2
Mg	mg/L	5.94	6.2	4.66	5.55	5.72	4.54
Mn	µg/L	77.6	44	52.5	19.9	37	46
Mo	µg/L	0.77	0.59	0.83	0.8	0.56	0.8
Ni	µg/L	0.67	0.84	0.93	1.17	1.1	1.29
Pb	µg/L	0.028	0.011	0.107	0.053	0.165	0.067
Sb	µg/L	0.09	0.094	0.08	0.09	0.085	0.092
Se	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sn	µg/L	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
Sr	µg/L	109	111	115	105	108	111
Th	µg/L	0.011	0.005	0.009	0.011	0.003	0.005
Ti	µg/L	0.5	0.8	1.7	0.6	0.5	0.9
Tl	µg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
U	µg/L	0.23	0.221	0.249	0.217	0.2	0.2
V	µg/L	0.2	0.225	0.38	0.06	0.139	0.24
Zn	µg/L	0.82	0.47	1.64	0.85	0.91	1.7
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe, Diss.	µg/L	7	8	20	<3	<3	8

3.5 Organic Constituents

Dissolved Organic Carbon (DOC, Table 3) and pesticides (Appendix A) were measured during the 2000-2001 study in composite samples collected from each basin. Various trace organic compounds including priority pollutants were analyzed for in the lake outfall (Section 3.6, Appendix B).

Levels of DOC were similar to those measured earlier and were within the range found in the Alberta lakes. On average, the West Basin (10.5 mg/L) contained somewhat higher concentrations of DOC than the East Basin (9.8 mg/L). This has attributed to the influence of the South Heart River that carries relatively high nutrient and dissolved organic carbon loadings as well as the higher levels of phytoplankton to the West Basin (Noton 1998).

All pesticide compounds analyzed were found to be below the detection method. Comparable results were obtained in the past.

3.6 Lake Outfall Water Quality

Water quality data collected during the 2000-2002 surveys for lake discharges from the East Basin to the Lesser Slave are provided in Table 5. In general, chemical water characteristics of the outfall are similar to those in the East Basin. The lake outfall was well oxygenated and had low levels of suspended solids and turbidity. Levels of dissolved solids ranged between 90 and 158 mg/L and were within those measured in the East Basin. DOC concentrations ranged between 9.3 and 13.3 mg/L.

Levels of nutrients (phosphorus and nitrogen) were within the range measured in the East Basin. Total Phosphorus levels varied between 0.013 and 0.040 mg/L and were below the ASWQG (AEP 1999) of 0.05 mg/L. Only one sample (from January 2002) showed total nitrogen levels slightly exceeding the guideline of 1 mg/L.

Levels of fecal bacteria were low (generally below 10/100 mL) and all results complied with water quality guideline for recreation.

In total, 119 trace organic compounds, including priority pollutants, were analyzed in lake outfall (Appendix B). Most of these compounds were below the detection limit of analytical methods employed. The levels of those detected (fatty acids[4], AOX[5]) do not indicate an anthropogenic organic contamination.

The outfall from the lake differed notably from lake's tributaries whose water quality was measured in the past (Noton 1998). Compared to the lake's tributaries, the outfall has more stable levels of most chemical variables and much lower concentrations of nutrients, metals and organic carbon.

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[4] Fatty acids were measured to indicate potential contamination with oil and grease.

[5] AOX is a measure of total amount of chlorinated organics present and used to evaluate pulp mill effluents and drinking water. AOX occurs naturally or being formed by chlorine-based beaching and disinfection.

Table 5 Lake outfall water quality data

SAMPLE DATE	D.O. (Field Meter) mg/L	PH (field) pH units	Conduc-tivity (Field) µS/cm	Water Temp deg C	Total Alkalinity $CaCO_3$ mg/L	Non Filterable Residue mg/L	Filterable Residue mg/L	Hardness $CaCO_3$ mg/L	Sodium Dissolved mg/L	Mg Dissolved mg/L	Silica Reactive mg/L
6-Mar-00	13.41	7.86	225	0.51	107	L1	158	101	11		0.6
1-Nov-00	12.15	8.2	193	3	92.4	22.4	132	80	8.7	5.6	L0.05
7-Dec-00	12.59	8	195	0.47	95.4	L1	113	89	9	6.6	0.7
9-Jan-01	14.34	8.15	212	0.47	106	L1	142	100	9.8	7.1	0.7
20-Feb-01	14.24	8.47	214	1.08	102	L1	132	100	9.5	6.9	L0.05
5-Apr-01	15.34	8.7	199	4	93.6	2.4	148	93	8.8	6.6	L0.05
2-May-01	12.73	8.53	140	5.1	70.1	L1	90	62	6.5	4.3	0.6
27-Jul-01	9.06	8.37	204	19.91	87.5	6	124	83	8.3	5.8	1.31
24-Oct-01	12.51	8.58	191	3.11	90.4	4	140	81	8.3	5.9	0.07
10-Jan-02	13.93	7.74	224	0.62	108	L1	128	100	10.2	6.6	0.1

SAMPLE DATE	P Total Dissolved mg/L	P Total (TP) mg/L	Sulphate mg/L	Chloride mg/L	Potassium mg/L	Calcium mg/L	True Color rel units	Conduc-tivity (Lab) µS/cm	Turbidity NTU	DOC mg/L	Bicarb-onate Calc. mg/L
6-Mar-00	0.009	0.013	13	2.2	3.2		10	130	0.6	11.4	130
1-Nov-00	0.0074	0.0402	10.4	1.1	2.8	22.8	10	202	12.1	10.1	113
7-Dec-00	0.0161	0.0254	10.2	1.3	2.9	24.9	20	212	2	10	116
9-Jan-01	0.0159	0.0231	11.7	1.2	3.2	30.1	10	234	2	12	129
20-Feb-01	0.0089	0.0233	11.8	2.2	3.1	29.8	5	236	1	13.3	125
5-Apr-01	0.0154	0.021	10.9	1.4	2.9	26.3	10	207	3	10.4	114
2-May-01	0.0073	0.023	7.7	1.3	1.9	17.8	20	151	4	9.3	85.5
27-Jul-01	0.0084	0.0245	9.2	2.3	2.8	23.6	10	198	4	9.9	107
24-Oct-01			9.2	1	2.4	22.9	10	197	4	11.1	110
10-Jan-02	0.0099	0.0173	10.8	1.6	3.7	30	10	237	2	12.5	131

SAMPLE DATE	Cyanide mg/L	Chloro-phyll-*a* mg/m^3	Nitrogen Nitrite mg/L	Nitrogen NO3 & NO2 mg/L	TKN mg/L	Ammonia Total mg/L	D.O. (Winkler) mg/L	BOD mg/L	Fluoride Dissolved mg/L	*Escherichia Coli* no./100 mL	Fecal Coliforms no./100 mL
6-Mar-00		1.2		0.042	0.58	0.038	13.3	0.6	0.11	L10	L10
1-Nov-00		13.7	0.006	0.046	0.54	0.02	12.28		0.09	10	20
7-Dec-00			0.01	0.068	0.63	0.19	12.52	3	0.11	L10	L10
9-Jan-01			0.012	0.089	0.57	0.15	14.3	1.7	0.11	L10	L10
20-Feb-01	0.001	27.9	0.022	0.082	0.7	L0.01	15.76	4.2	0.13	L10	L10
5-Apr-01		15.4	L0.003	0.005	0.5	0.01	15.59	2.4	0.09		
2-May-01	L0.004	3.4	L0.003	0.041	0.5	L0.01	12.7		0.08	L10	L10
27-Jul-01	L0.004	3.8	L0.003	L0.003	0.77	L0.01	9.81		0.09	10	10
24-Oct-01	L0.002	16.5	L0.003	0.004	0.51	L0.01	12.65		0.1	10	10
10-Jan-02			L0.003	L0.003	1.07	0.04	13.32	0.8	0.11	L10	L10

L – "less than" or below the detection limit

4.0 SUMMARY AND CONCLUSIONS

- Lesser Slave Lake is the third largest lake in Alberta. It is a popular tourist destination and a recognized, biologically significant area for bird life. The lake is a source of water for agriculture, forestry and domestic and municipal uses. It supports major sport, commercial and domestic fisheries.

- Residents in the LSL watershed have been concerned with the health of their lake and the quality of life it provides. In response to various water management concerns, AENV conducted two comprehensive water quality and limnological investigations. The first one was conducted between 1991 and 1993 and the second between 2000 and 2001.

- The results of the 1991-1993 surveys are presented in the report titled "*Water Quality of Lesser Slave Lake and Its Tributaries, 1991-93*" (Noton 1998). This report summarizes results of limnological and water quality surveys conducted on the Lesser Slave Lake and its outfall between 2000 and 2002.

- Lake water quality results from both studies are comparable and allow for similar conclusions:
  - The lake is well mixed due to wind action and thermal stratification is week and transitory.

  - Mixing allows good oxygen distribution throughout the water column. LSL is well oxygenated even in winter and much of the water column contains more than 5 mg/L of dissolved oxygen year round.

  - The water is of calcium bicarbonate type. Levels of dissolved solids are relatively low for the central Alberta lakes and ranged between 105 and 118 mg/L. Slightly (generally less than 10%) higher levels of dissolved solids were measured in the West Basin than in the East Basin.

  - Turbidity in the central areas of the lake is associated with algae levels. Total suspended solids were low and varied between 2 and 6 mg/L.

  - Concentrations of nutrients (nitrogen and phosphorus) were moderately high. The West Basin has had continuously higher concentrations of nutrients compared to the East Basin. The 1991-93 studies showed that phosphorus was being released from bottom sediments in spring and summer contributing to peak phosphorus levels in late summer. The subsequent, 2000-2001 surveys confirm this pattern as nutrient levels were within the range measured in the past.

  - Concentrations of chlorophyll-*a*, the main measure of algal density, have been high for the amount of phosphorus present. In terms of chlorophyll-*a* levels, the West and East basins rank very high on the productivity scale for Alberta

lakes and can be categorized as hypereutrophic (super productive). Based on the Total Phosphorus concentrations, the East Basin and West Basin fall within mesotrophic (medium productivity) and eutrophic (high productivity) categories respectively.

- Most water quality variables, including metals and trace elements as well as pesticides, complied with Alberta Surface Water Quality Guidelines for the protection of aquatic life. Exceptions were some total nitrogen and total phosphorus levels reflecting the eutrophic nature of the lake.

- Lake outfall was sampled on 10 occasions between 2000 and 2002. Water quality parameters measured (including nutrients, trace organics and fecal coliform bacteria), complied with Alberta Surface Water Quality Guidelines for the protection of aquatic life.

- The main potential concern with respect to water quality is the high nutrient (phosphorus) and algal content, particularly in the West Basin. About 80% of external loading of phosphorus (P) is retained in the lake (Noton 1998). In 2005 AENV initiated paleolimnological studies with the following objectives:

  - To gain knowledge of the natural range of water quality that existed before onset of human activities

  - To identify the timing and magnitude of changes leading to the present state

  - To determine if the present state of water quality in the lake has been influenced by anthropogenic (man caused) activities in the lake basin and watershed

  The paleolimnological studies will examine lake sediments and derive from the sediment archive information about water chemistry and productivity that predate presumed changes accompanying human activity in the lake basin.

5.0 REFERENCES

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Appendix A Pesticide concentrations in composite samples from euphotic zone

Compound	East Basin Euphotic Composite			West Basin Euphotic Composite		
	28-Jul-00	30-Aug-00	5-Oct-00	27-Jul-00	30-Aug-00	5-Oct-00
2,4-D µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
2,4-DB µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
DICHLORPROP(2,4-DP) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
ALPHA-BENZENEHEXACHLORIDE µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
ALPHA-ENDOSULFAN µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
GAMMA-BENZENEHEXACHLORIDE µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
METHOXYCHLOR (P,P'-METHOXYCHLOR) µg/L	L0.03	L0.03	L0.03	L0.03	L0.03	L0.03
ATRAZINE µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
BROMACIL µg/L	L0.03	L0.03	L0.03	L0.03	L0.03	L0.03
BROMOXYNIL µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
CARBATHIIN (CARBOXIN) µg/L	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
CYANAZINE µg/L	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
DIAZINON µg/L	L0.005	L0 005	L0.005	L0.005	L0.005	L0.005
DICAMBA (BANVEL) µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02
DICLOFOP-METHYL (HOEGRASS) µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02
DISULFOTON (DI-SYSTON) µg/L	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2
DIURON µg/L	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2
CHLORPYRIFOS-ETHYL (DURSBAN) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
ETHALFLURALIN (EDGE) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
ETHION µg/L	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
GUTHION µg/L	L0.2	L0.2	L0.2	L0.2	L0.2	L0.2
CLOPYRALID (LONTREL) µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02
MALATHION µg/L	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
MCPA µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
MCPB µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02
MCPP (MECOPROP) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
PICLORAM (TORDON) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
PHORATE (THIMET) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
TERBUFOS µg/L	L0.03	L0.03	L0.03	L0.03	L0.03	L0.03
TRIALLATE (AVADEXBW) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
TRIFLURALIN(TREFLAN) µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
IMAZAMETHABENZ-METHYL µg/L	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
DESETHYL ATRAZINE µg/L	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
DEISOPROPYL ATRAZINE µg/L	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
QUINCLORAC µg/L	L0.005	L0.005	L0.005	L0.005	L0.005	L0.005
IMAZETHAPYR µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02
FENOXAPROP-P-ETHYL µg/L	L0.04	L0.04	L0.04	L0.04	L0.04	L0.04
PYRIDABEN µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02
DIMETHOATE (CYGON) µg/L	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
IMAZAMOX µg/L	L0.02	L0.02	L0.02	L0.02	L0.02	L0.02

L – "Less Than" or below the detection limit

Appendix B Trace organics in lake outfall

Compound Name	Sample Date			
	6-Mar-00	1-Nov-00	20-Feb-01	24-Oct-01
1,1,1,2-TETRACHLOROETHANE µg/L			L0.1	
1,1,1-TRICHLOROETHANE µg/L			L0.1	
1,1,2,2-TETRACHLOROETHANE µg/L			L0.1	
1,1,2-TRICHLOROETHANE µg/L			L0.1	
1,1-DICHLOROETHANE µg/L			L0.1	
1,1-DICHLOROETHYLENE µg/L			L0.1	
1,1-DICHLOROPROPYLENE µg/L			L0.1	
1,2,3-TRICHLOROBENZENE µg/L			L0.1	
1,2,3-TRICHLOROPROPANE µg/L			L0.1	
1,2,4-TRICHLOROBENZENE µg/L			L0.1	
1,2,4-TRICHLOROBENZENE µg/L			L0.1	
1,2,4-TRIMETHYLBENZENE µg/L			L0.1	
1,2-DIBROMO-3-CHLOROPROPANE µg/L			L0.3	
1,2-DIBROMOETHANE µg/L			L0.1	
1,2-DICHLOROBENZENE µg/L			L0.1	
1,2-DICHLOROETHANE µg/L			L0.1	
1,2-DICHLOROPROPANE µg/L			L0.1	
1,2-DIPHENYLHYDRAZINE µg/L			L0.1	
1,3,5-TRIMETHYLBENZENE µg/L			L0.1	
1,3-DICHLOROBENZENE µg/L			L0.1	
1,3-DICHLOROPROPANE µg/L			L0.1	
1,4-DICHLOROBENZENE µg/L			L0.1	
12,14-DICHLORODEHYDROABIETIC ACID µg/L	L0.2		L0.2	
12-CHLORODEHYDROABIETIC ACID µg/L	L0.2		L0.2	
14-CHLORODEHYDROABIETIC ACID µg/L	L0.2		L0.2	
2,2-DICHLOROPROPANE µg/L			L0.1	
2,4,6-TRICHLOROPHENOL µg/L			L0.1	
2,4-DICHLOROPHENOL µg/L			L0.1	
2,4-DIMETHYLPHENOL µg/L			L0.2	
2,4-DINITROPHENOL µg/L			L0.1	
2,4-DINITROTOLUENE µg/L			L0.1	
2,6-DINITROTOLUENE µg/L			L0.1	
2-CHLOROETHYLVINYLETHER µg/L			L0.4	
2-CHLORONAPHTHALENE µg/L			L0.1	
2-CHLOROPHENOL µg/L			L0.2	
2-CHLOROTOLUENE µg/L			L0.1	
2-METHYL-4,6-DINITROPHENOL µg/L			L0.1	
2-NITROPHENOL µg/L			L0.1	
4-CHLORO-3-METHYLPHENOL µg/L			L0.1	
4-CHLOROTOLUENE µg/L			L0.1	
4-NITROPHENOL µg/L			L0.1	
9,10-DICHLOROSTEARIC ACID µg/L	L1		L1	
ABIETIC ACID µg/L	L1		L1	
ACENAPHTHENE µg/L			L0.1	
ACENAPHTHYLENE µg/L			L0.1	

Compound Name	Sample Date			
	6-Mar-00	1-Nov-00	20-Feb-01	24-Oct-01
ANTHRACENE µg/L			L0.1	
AOX ADSORBABLE ORGANIC HALIDES mg/L		0.002	0.002	0.007
ARACHIDIC ACID µg/L	0.1		0.2	
BENZENE µg/L			L0.1	
BENZIDINE µg/L			L0.2	
BENZO(A)ANTHRACENE µg/L			L0.1	
BENZO(A)PYRENE µg/L			L0.1	
BENZO(B)FLUORANTHENE µg/L			L0.1	
BENZO(G,H,I)PERYLENE µg/L			L0.2	
BENZO(K)FLUORANTHENE µg/L			L0.1	
BROMOBENZENE µg/L			L0.1	
BROMOFORM µg/L			L0.5	
BROMOMETHANE µg/L			L0.1	
CARBON TETRACHLORIDE µg/L			L0.1	
CHLOROBENZENE µg/L			L0.1	
CHLOROETHANE µg/L			L0.1	
CHLOROFORM µg/L			L0.1	
CHRYSENE µg/L			L0.1	
CIS-1,2-DICHLOROETHENE µg/L			L0.1	
CIS-1,3-DICHLOROPROPENE µg/L			L0.3	
DEHYDROABIETIC ACID µg/L	L0.2		L0.2	
DIBENZO(A,H)ANTHRACENE µg/L			L0.5	
DIBROMOCHLOROMETHANE µg/L			L0.1	
DIBROMOMETHANE µg/L			L0.1	
DICHLOROBROMOMETHANE µg/L			L0.1	
ETHYL BENZENE µg/L			L0.1	
FLUORANTHENE µg/L			L0.1	
FLUORENE µg/L			L0.1	
HEPTADECANOIC ACID %	98.7		74.7	
HEXACHLOROBUTADIENE µg/L			L0.3	
HEXACHLOROBUTADIENE µg/L			L0.5	
HEXACHLOROCYCLOPENTADIENE µg/L			L0.1	
HEXACHLOROETHANE µg/L			L0.5	
INDENO(1,2,3-C,D)PYRENE µg/L			L0.1	
ISOPHORONE µg/L			L0.1	
ISOPIMARIC ACID µg/L	L0.2		L0.2	
ISOPROPYLBENZENE µg/L			L0.1	
LEVOPIMARIC ACID µg/L	L2		L2	
LINOLEIC ACID µg/L	0.2		1.5	
LINOLENIC ACID µg/L	0.7		4	
M- + P-XYLENE µg/L			L0.1	
METHYLENE CHLORIDE µg/L			L2	
MYRISTIC ACID µg/L	L2		14.2	
NAPHTHALENE µg/L			L0.1	
NAPHTHALENE µg/L			L0.1	
N-BUTYLBENZENE µg/L			L0.1	
NEOABIETIC ACID µg/L	L2		L2	
NITROBENZENE µg/L			L0.1	

Compound Name	Sample Date			
	6-Mar-00	1-Nov-00	20-Feb-01	24-Oct-01
N-NITROSODI-N-PROPYLAMINE µg/L			L0.2	
N-NITROSODIPHENYLAMINE µg/L			L0.1	
N-PROPYLBENZENE µg/L			L0.1	
OLEIC ACID µg/L	0.5		2.3	
O-METHYL PODOCARPIC ACID %	87.7		69.3	
O-XYLENE µg/L			L0.1	
PALMITIC ACID µg/L	L10		4.2	
PALUSTRIC ACID µg/L	L2		L2	
PENTACHLOROPHENOL µg/L			L0.1	
PHENANTHRENE µg/L			L0.1	
PHENOL µg/L			L0.1	
PIMARIC ACID µg/L	L0.2		L0.2	
P-ISOPROPYLTOLUENE µg/L			L0.1	
PYRENE µg/L			L0.1	
SANDARACOPIMARIC ACID µg/L	L0.3		0.9	
SEC-BUTYLBENZENE µg/L			L0.1	
STEARIC ACID µg/L	L5		L5	
STYRENE µg/L			L0.1	
TERT-BUTYLBENZENE µg/L			L0.1	
TETRACHLOROETHYLENE µg/L			L0.3	
TOLUENE µg/L			L0.1	
TRANS-1,2-DICHLOROETHENE µg/L			L0.1	
TRANS-1,3-DICHLOROPROPENE µg/L			L0.3	
TRICHLOROETHYLENE µg/L			L0.1	
TRICHLOROFLUOROMETHANE µg/L			L0.1	
VINYL CHLORIDE µg/L			L0.5	

L – "Less Than" or below the detection limit